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THERMAL EXPANSION OF FIFTEEN DRILL CORE SAMPLES FROM THE UNDERGROUND RESEARCH LABORATORY SITE, DRILL HOLE NUMBER ONE

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Project ERP-4.4.0.3.01
Underground Nuclear Waste Repository

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by

K.E. Bell* and G.R. Lemieux**

INTRODUCTION

The work described forms a contribution to the determination of the thermal and mechanical properties of potential host rocks for underground nuclear waste disposal, CANMET Project 4.4.0.3.01, "Underground Nuclear Waste Repository".

Fifteen rock samples were supplied by T.J. Katsube, Resource Geophysics and Geochemistry Division, Geological Survey of Canada. All samples were sections of drill core, measuring about 45 mm in diameter and 60 to 70 mm long. The samples were identified individually as follows, the numbers representing their depth in metres:

URL-1 - 46.5Q
URL-1 - 68.6Q
URL-1 - 131.4Q
URL-1 - 177.2Q
URL-1 - 230.6Q
URL-1 - 254.4Q
URL-1 - 302.5Q
URL-1 - 357.3Q
URL-1 - 397.9Q
URL-1 - 443.3Q
URL-1 - 496.8Q
URL-1 - 527.5Q
URL-1 - 592.7Q
URL-1 - 616.0Q
URL-1 - 662.5Q

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PROCEDURES AND RESULTS

To preserve, insofar as possible, the integrity of the samples for possible further work, specimens of essentially triangular cross-section (about 8-10 mm per side) were cut from the periphery of the core, parallel to the longitudinal axis. The specimens were cut to $50.8 \pm 5.08 \times 10^{-2}$mm, with ends plane and parallel, using a precision diamond wafering saw. The actual length of each specimen was measured to the nearest 2.54×10^{-2}mm.

The thermal expansion behaviour of the specimens was measured dynamically between room temperature and about 500°C in a vertical tube-type dilatometer. The principal components of the apparatus were a nichrome-wound furnace having a uniform hot zone 75 mm long; a fused quartz tube closed at the bottom with a plane quartz disc set perpendicular to the longitudinal axis to support the specimen; and a fused quartz push-rod to translate dimensional changes in the specimen directly to an Ames dial rigidly mounted on the upper end of the tube. Specimen temperature was determined using a Pt/Pt10%Rh thermocouple with the hot junction in contact with the mid-length of the specimen, positioned centrally in the uniform hot zone of the furnace.

Heating of the furnace was manually controlled. A stable heating rate was established by about 75°C, above which the rate was maintained at 10 ± 1°C/min. Temperatures, to the nearest 1°C, and elongation, to the nearest 2.54×10^{-3}mm, were read and recorded at 3-min intervals throughout the early part of the run (when frequent adjustment was necessary) and each 2 min thereafter. Elongation was calculated as a percentage of initial length and is shown as a function of temperature in Fig. 1 to 15. The data from which the curves were plotted is given for all samples in Appendix A.

No corrections were made to compensate for expansion of the fused quartz because this is very small and regular, i.e., 0.585×10^{-6} cm/cm/°C from 0° to 1200°C.

After the specimen was removed from the furnace and cooled to room temperature, its length was measured to the nearest 2.54×10^{-2}mm, and the permanent, or irreversible expansion was calculated.

OBSERVATIONS

The thermal expansion behaviour of this suite of samples reflects that found for all granitic samples examined to date within the Project. No expansion of the bulk material is observed between room temperature and about 50°C, attributed to expansion of the individual grains being taken up in the porosity of the rock. Above that temperature the rate of expansion increases with increasing temperature.

For this set of samples, there is a trend for total expansion at all temperatures to decrease with increasing depth. A marked anomaly can be observed between Sample URL-1 - 357.3 and the next adjacent samples above (302.5) and below (397.9): at temperatures of 200°C and lower the subject sample shows expansion about 30% lower than its nearest neighbours. Heating of the rock in the zone from 300 to 400 metres deep could give rise to above-normal stresses. Similar, but less extensive anomalies are found at 177.2 and 254.4 metres deep.

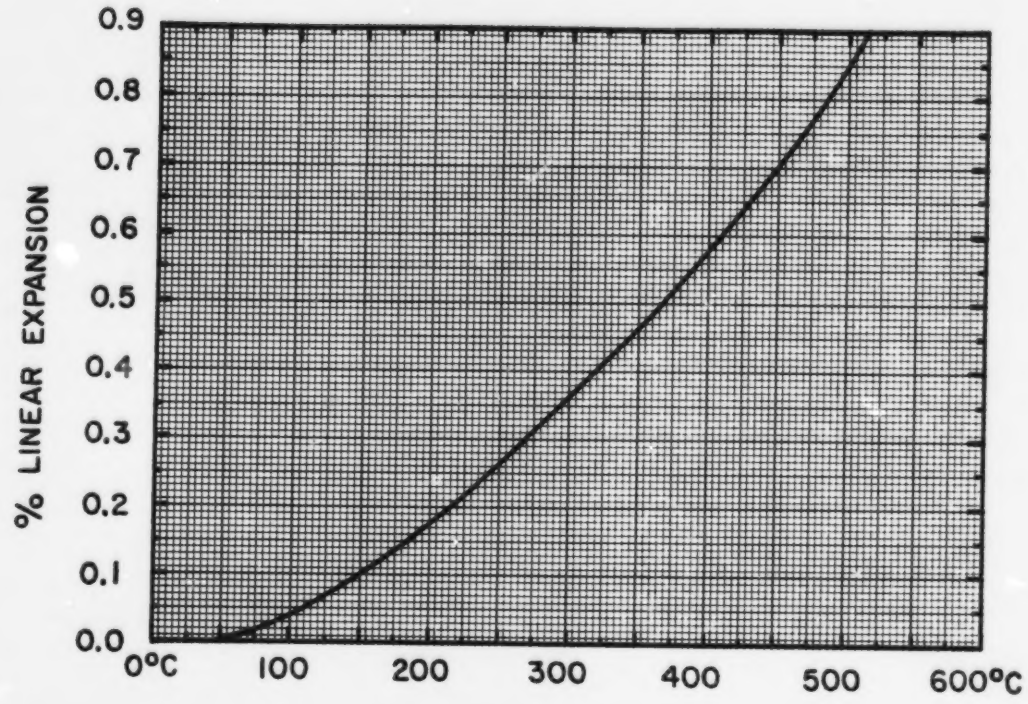

Fig. 1 - Linear thermal expansion of Sample URL-1 - 46.5Q.

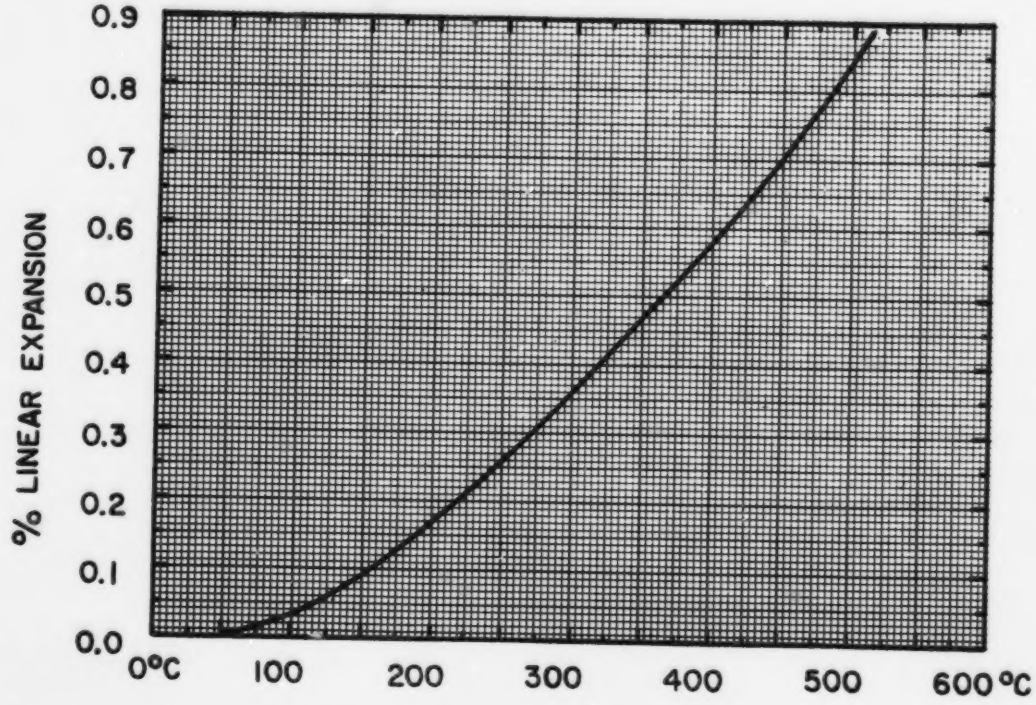

Fig. 2 - Linear thermal expansion of Sample URL-1 - 68.6Q.

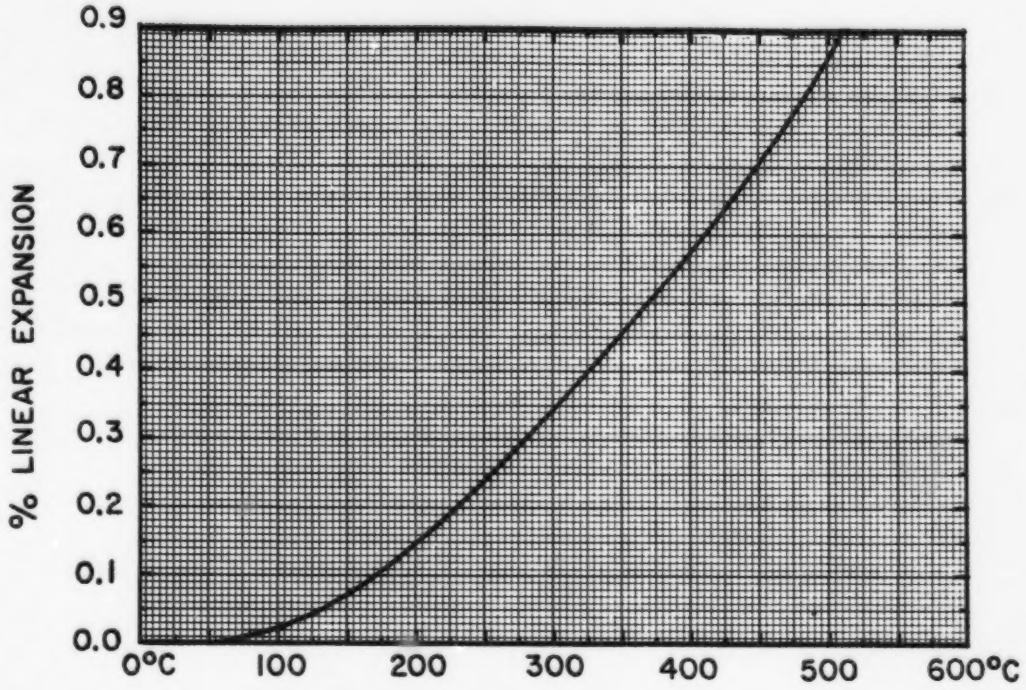

Fig. 3 - Linear thermal expansion of Sample URL-1 - 131.4Q.

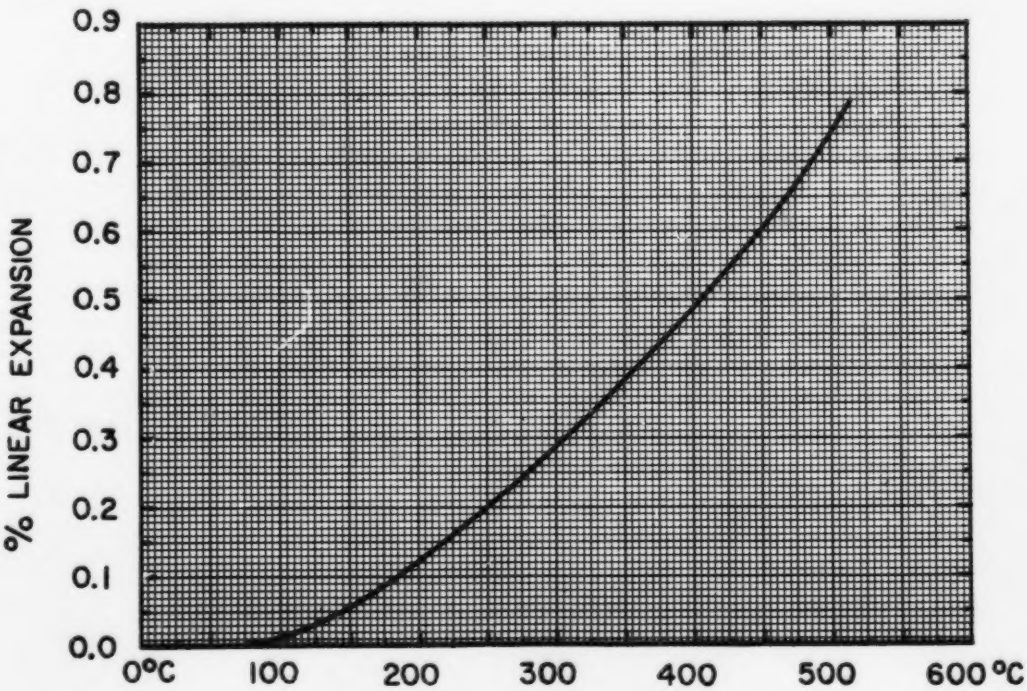

Fig. 4 - Linear thermal expansion of Sample URL-1 - 177.2Q.

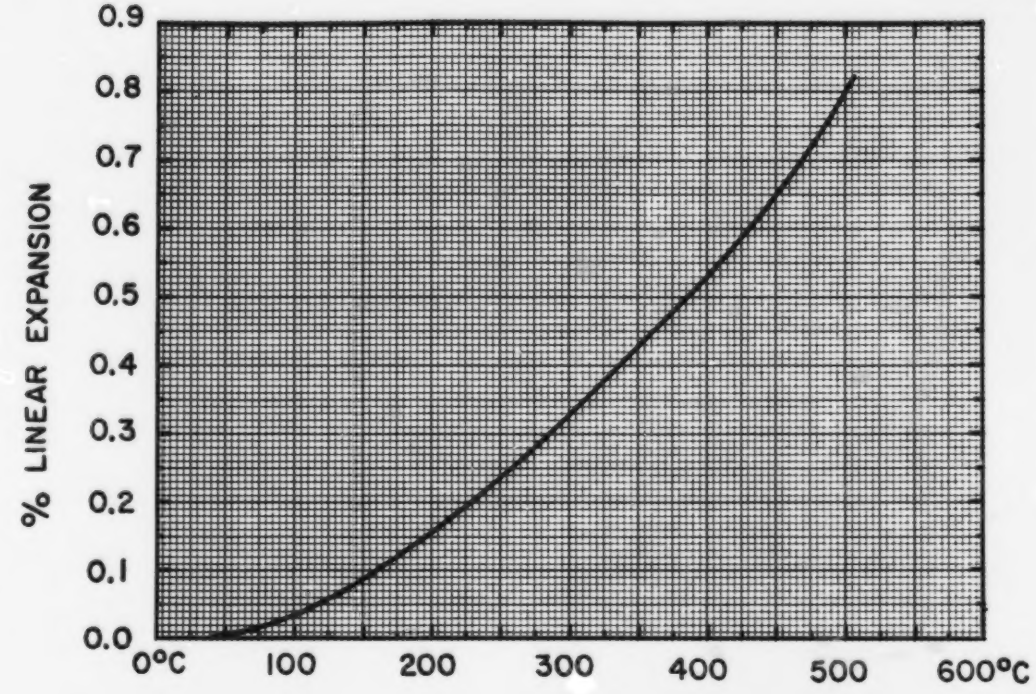

Fig. 5 - Linear thermal expansion of Sample URL-1 - 230.6Q.

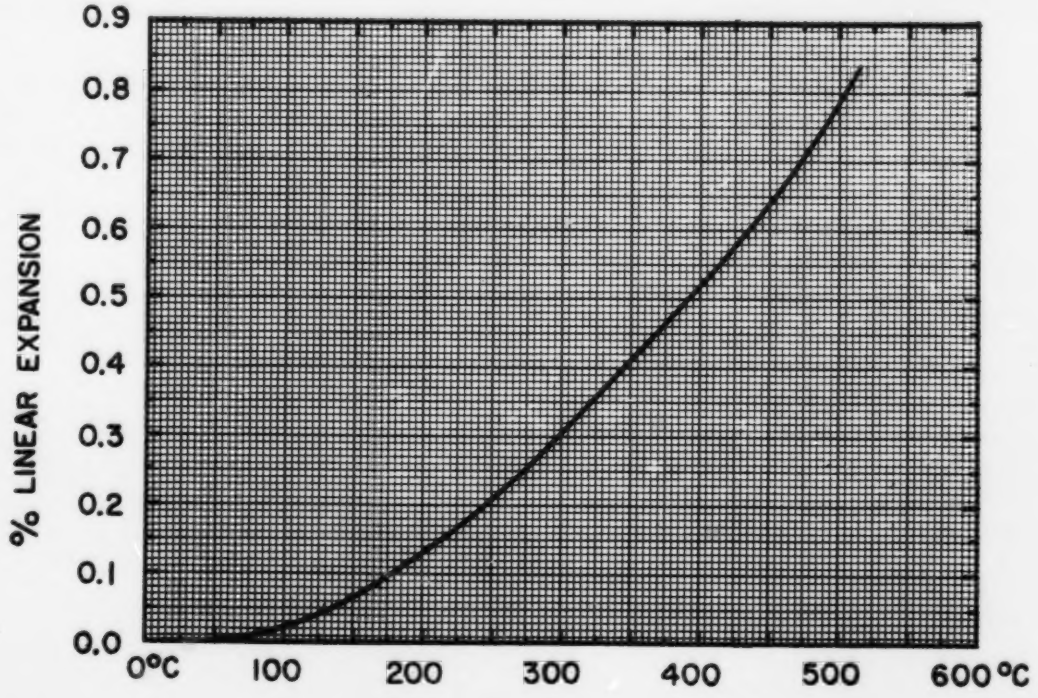

Fig. 6 - Linear thermal expansion of Sample URL-1 - 254.4Q.

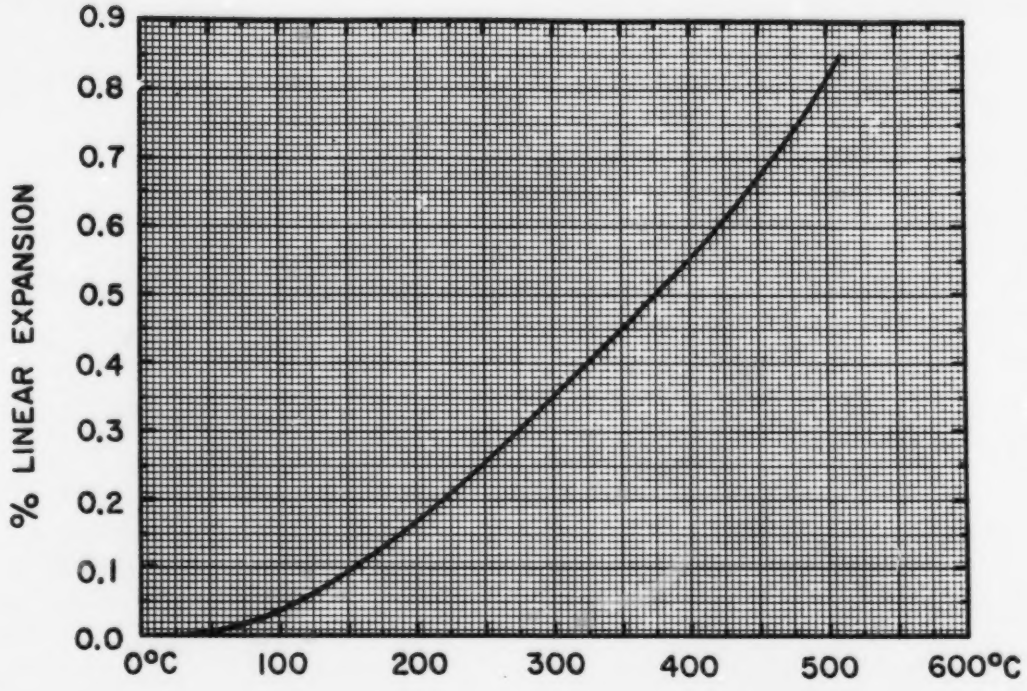

Fig. 7 - Linear thermal expansion of Sample URL-1 - 302.5Q.

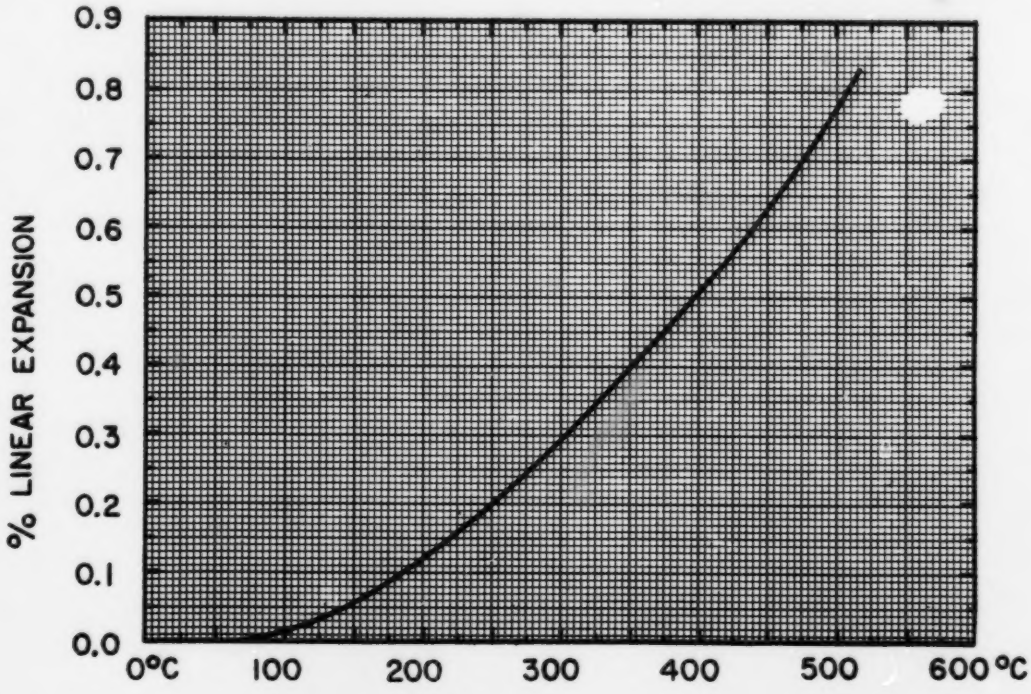

Fig. 8 - Linear thermal expansion of Sample URL-1 - 357.3Q.

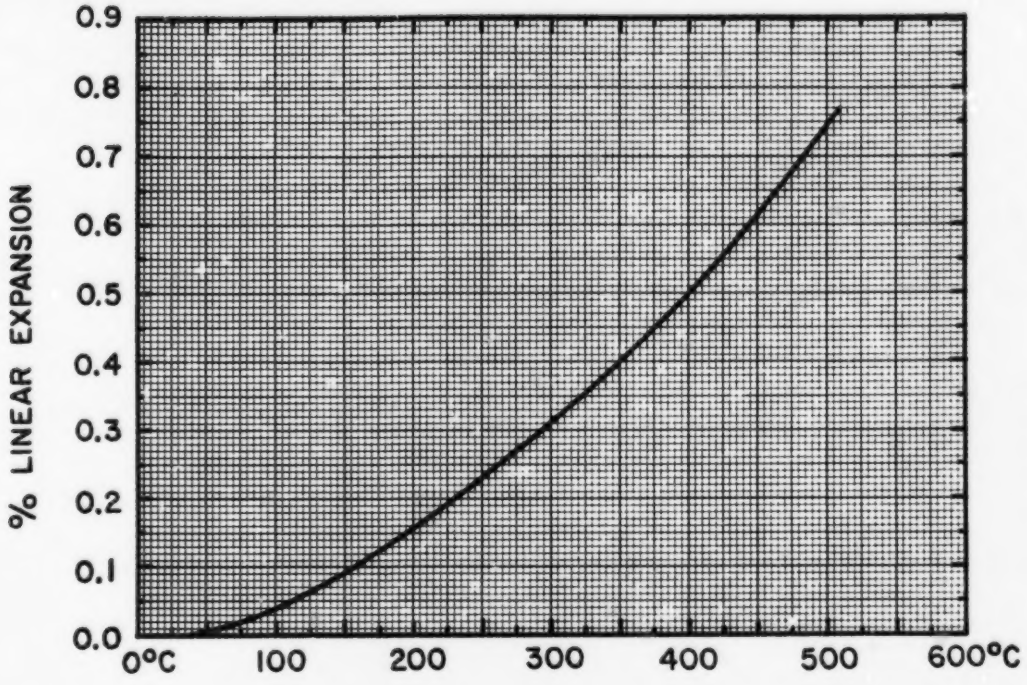

Fig. 9 - Linear thermal expansion of Sample URL-1 - 397.9Q.

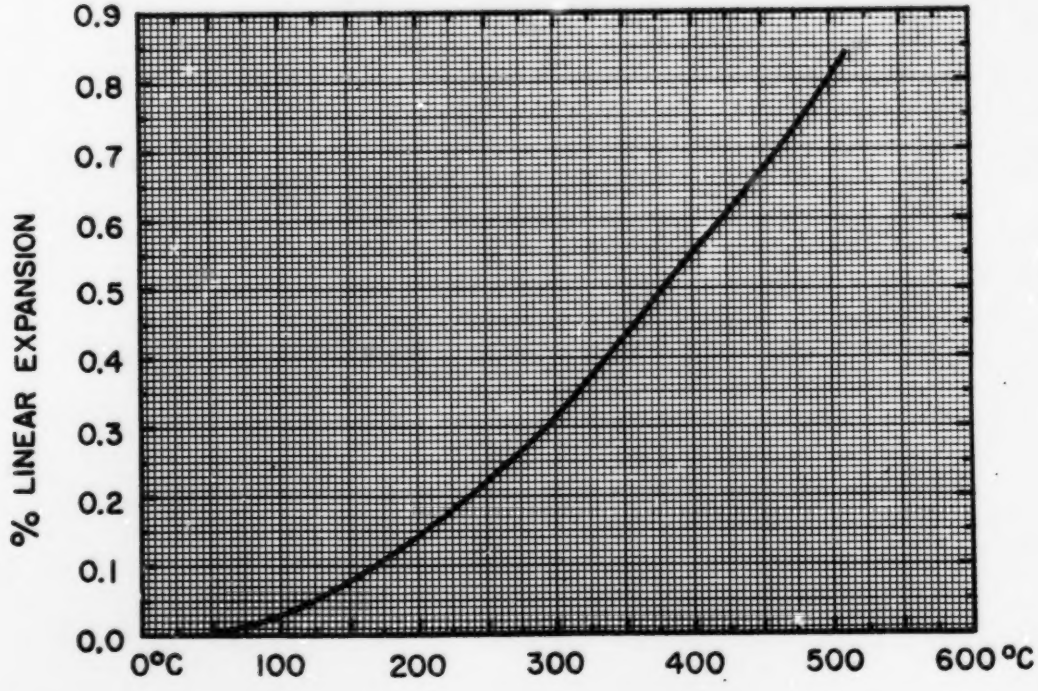

Fig. 10 - Linear thermal expansion of Sample URL-1 - 443.3Q.

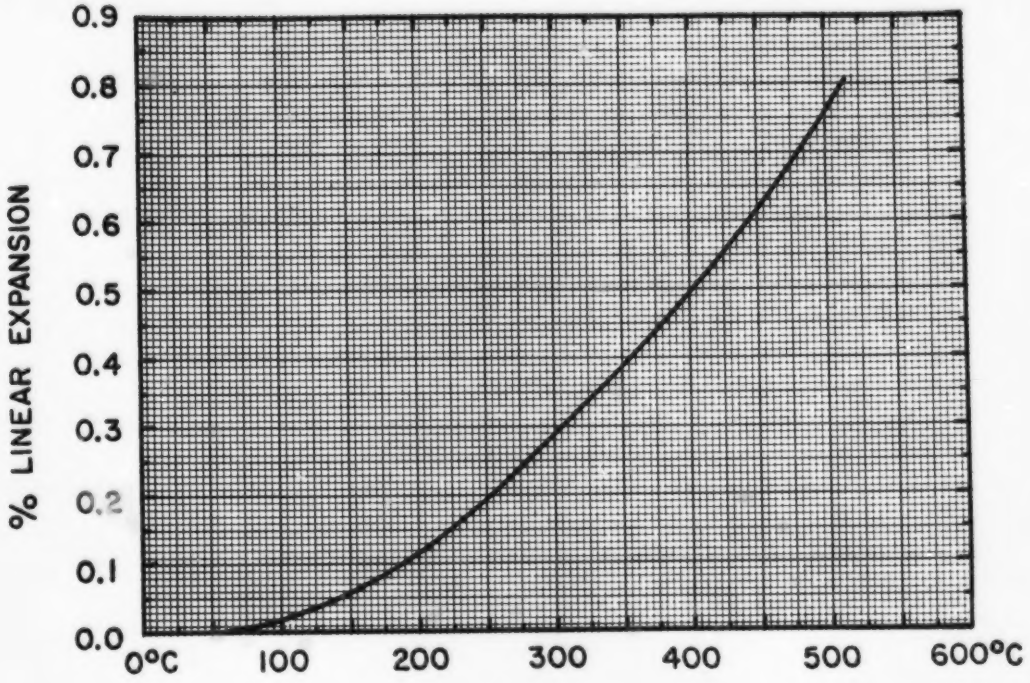

Fig. 11 - Linear thermal expansion of Sample URL-1 - 496.8Q.

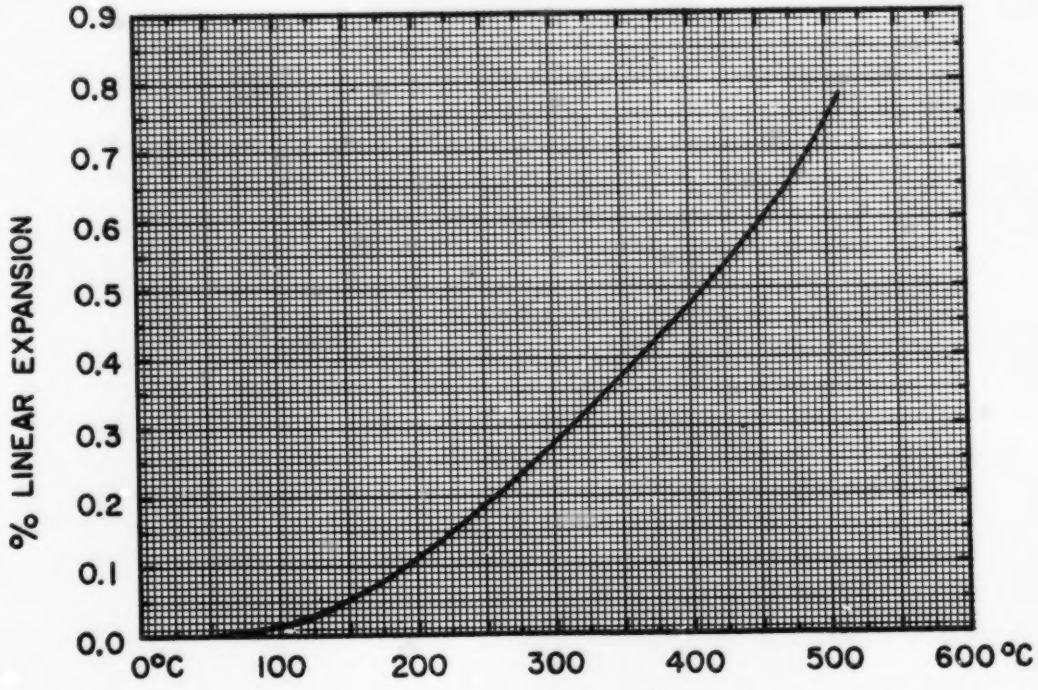

Fig. 12 - Linear thermal expansion of Sample URL-1 - 527.5Q.

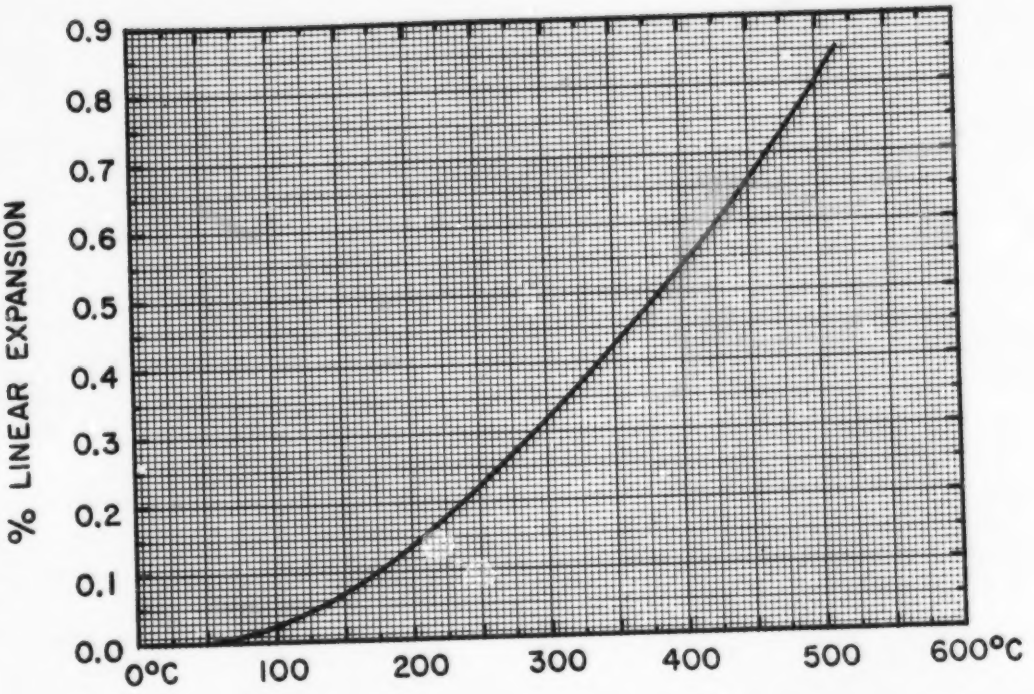

Fig. 13 - Linear thermal expansion of Sample URL-1 - 592.7Q.

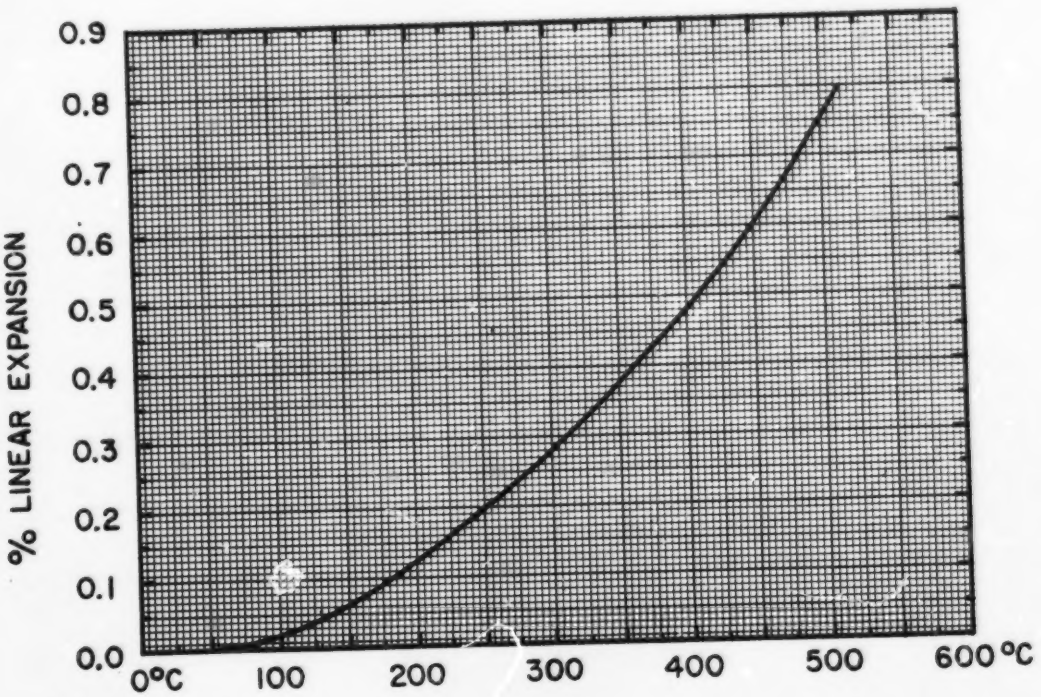

Fig. 14 - Linear thermal expansion of Sample URL-1 - 616.0Q.

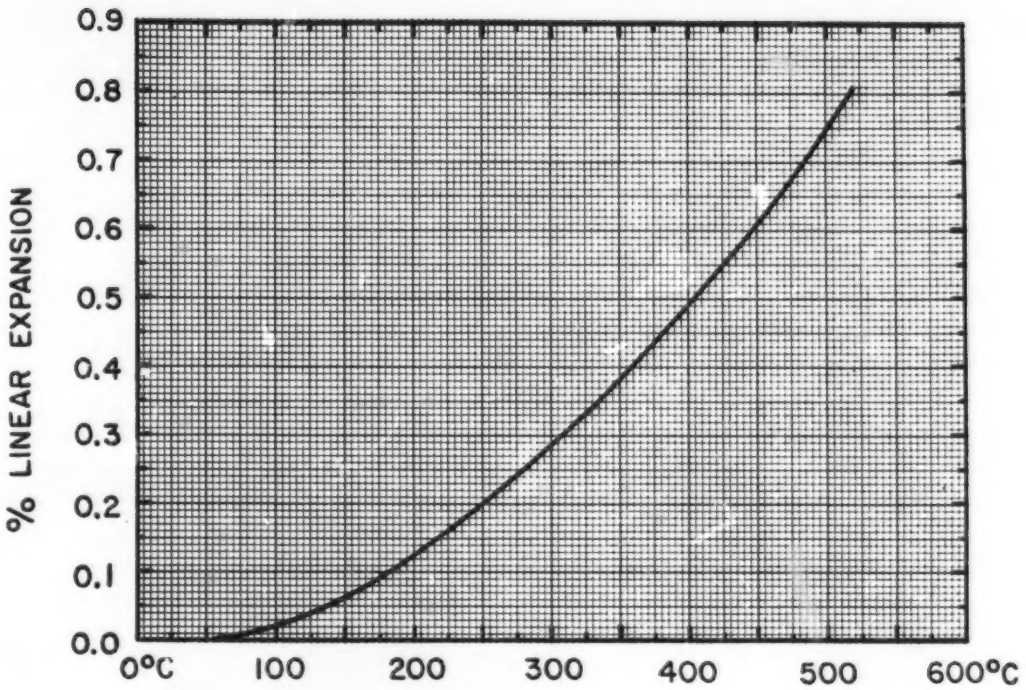

Fig. 15 - Linear thermal expansion of Sample URL-1 - 662.5Q.

APPENDIX A

Thermal Expansion Data

Project No. 4.4.0.3.01

Date: Sept. 24, 1982

Sample No: URL-1 - 46.5Q

Original Length: 2.000 in.

Length after test: 2.003 in.

Irreversible expansion: 0.15 %

Elapsed Time (min)	Temperature (^{o}C)	Elongation (%)
0	22	0.00
3	32	0.00
6	55	0.005
9	83	0.023
12	112	0.05
15	141	0.09
18	173	0.135
21	204	0.185
24	235	0.235
26	255	0.275
28	275	0.315
30	295	0.355
32	315	0.395
34	335	0.435
36	355	0.475
38	375	0.520
40	395	0.568
42	415	0.615
44	435	0.665
46	456	0.718
48	476	0.773
50	496	0.835
52	516	0.905

Date: Sept. 27, 1982

Sample No: URL-1 - 68.6Q

Original Length: 2.002 in.

Length after test: 2.004 in.

Irreversible expansion: 0.10 %

Elapsed Time (min)	Temperature (^{o}C)	Elongation (%)
0	21	0.00
3	31	0.00
6	54	0.003
9	80	0.02
12	109	0.04
15	138	0.075
18	168	0.12
21	199	0.17
24	230	0.225
26	251	0.26
28	271	0.30
30	290	0.34
32	310	0.38
34	330	0.423
36	350	0.468
38	370	0.513
40	390	0.558
42	410	0.605
44	431	0.650
46	451	0.705
48	471	0.760
50	492	0.818
52	513	0.890

Project No. 4.4.0.3.01

Date: Sept. 28, 1982

Sample No: URL-1 - 131.4Q

Original Length: 2.002 in.

Length after test: 2.006 in.

Irreversible expansion: 0.20%

Elapsed Time (min)	Temperature (°C)	Elongation (%)
0	21	0.00
3	34	0.00
6	59	0.003
9	86	0.015
12	115	0.035
15	144	0.065
18	174	0.108
21	205	0.155
24	235	0.21
26	255	0.253
28	275	0.293
30	295	0.335
32	315	0.378
34	335	0.42
36	355	0.463
38	375	0.510
40	395	0.560
42	415	0.610
44	435	0.663
46	456	0.715
48	476	0.775
50	495	0.840
52	515	0.910

Date: Sept. 29, 1982

Sample No: URL-1 - 177.2Q

Original Length: 1.997 in.

Length after test: 2.000 in.

Irreversible expansion: 0.15%

Elapsed Time (min)	Temperature (°C)	Elongation (%)
0	21	0.00
3	33	0.00
6	58	0.00
9	86	0.005
12	115	0.02
15	145	0.048
18	175	0.085
21	205	0.13
24	235	0.175
26	255	0.208
28	275	0.24
30	296	0.275
32	316	0.315
34	336	0.355
36	356	0.395
38	375	0.435
40	395	0.475
42	415	0.520
44	435	0.565
46	455	0.613
48	475	0.665
50	495	0.725
52	515	0.790

Project No. 4.4.0.3.01

Date: Sept. 30, 1982

Sample No: URL-1 - 230.6Q

Original Length: 2.000 in.

Length after test: 2.004 in.

Irreversible expansion: 0.20%

Elapsed Time (min)	Temperature (°C)	Elongation (%)
0	23	0.00
3	30	0.00
6	50	0.003
9	75	0.015
12	106	0.04
15	137	0.07
18	168	0.11
21	199	0.155
24	230	0.20
26	250	0.235
28	271	0.273
30	292	0.31
32	312	0.35
34	332	0.39
36	352	0.43
38	372	0.47
40	392	0.513
42	412	0.555
44	432	0.600
46	452	0.655
48	472	0.710
50	492	0.765
52	512	0.825

Date: Oct. 1, 1982

Sample No: URL-1 - 254.4Q

Original Length: 2.004 in.

Length after test: 2.009 in.

Irreversible expansion: 0.25%

Elapsed Time (min)	Temperature (°C)	Elongation (%)
0	23	0.00
3	36	0.00
6	61	0.003
9	89	0.015
12	118	0.035
15	147	0.06
18	176	0.10
21	205	0.14
24	235	0.185
26	255	0.215
28	275	0.253
30	295	0.295
32	315	0.338
34	335	0.38
36	355	0.423
38	375	0.465
40	395	0.508
42	415	0.553
44	435	0.600
46	455	0.653
48	475	0.710
50	495	0.765
52	515	0.840

Project No. 4.4.0.3.01

Date: Oct. 4, 1982

Sample No: URL-1 - 302.5Q

Original Length: 2.000 in.

Length after test: 2.004 in.

Irreversible expansion: 0.20%

Elapsed Time (min)	Temperature (°C)	Elongation (%)
0	21	0.00
3	30	0.00
6	50	0.005
9	75	0.02
12	104	0.04
15	133	0.073
18	163	0.115
21	194	0.16
24	225	0.21
26	246	0.248
28	266	0.285
30	286	0.323
32	307	0.365
34	327	0.405
36	347	0.445
38	367	0.49
40	388	0.533
42	408	0.575
44	428	0.625
46	449	0.675
48	469	0.725
50	490	0.785
52	510	0.850

Date: Oct. 5, 1982

Sample No: URL-1 - 357.3Q

Original Length: 2.003 in.

Length after test: 2.007 in.

Irreversible expansion: 0.20%

Elapsed Time (min)	Temperature (°C)	Elongation (%)
0	21	0.00
3	40	0.00
6	64	0.00
9	92	0.01
12	121	0.03
15	150	0.055
18	180	0.09
21	210	0.135
24	240	0.185
26	259	0.218
28	278	0.253
30	297	0.288
32	316	0.328
34	336	0.365
36	355	0.405
38	375	0.45
40	395	0.495
42	415	0.540
44	435	0.590
46	455	0.643
48	475	0.700
50	495	0.760
52	515	0.830

Project No. 4.4.0.3.01

Date: Oct. 6, 1982

Sample No: URL-1 - 397.9Q

Original Length: 2.003 in.

Length after test: 2.007 in.

Irreversible expansion: 0.20%

Elapsed Time (min)	Temperature (°C)	Elongation (%)
0	21	0.00
3	30	0.00
6	51	0.003
9	77	0.02
12	105	0.04
15	135	0.075
18	165	0.11
21	196	0.15
24	226	0.195
26	247	0.225
28	267	0.258
30	287	0.288
32	308	0.325
34	328	0.36
36	348	0.395
38	369	0.438
40	390	0.478
42	410	0.520
44	430	0.565
46	450	0.615
48	470	0.665
50	490	0.718
52	510	0.770

Date: Oct. 7, 1982

Sample No: URL-1 - 443.3Q

Original Length: 2.003 in.

Length after test: 2.007 in.

Irreversible expansion: 0.20%

Elapsed Time (min)	Temperature (°C)	Elongation (%)
0	22	0.00
3	30	0.00
6	50	0.00
9	77	0.015
12	106	0.035
15	135	0.06
18	166	0.095
21	197	0.14
24	228	0.188
26	249	0.223
28	270	0.258
30	290	0.295
32	310	0.335
34	331	0.385
36	351	0.435
38	370	0.483
40	390	0.528
42	410	0.573
44	430	0.618
46	450	0.668
48	470	0.720
50	491	0.775
52	511	0.838

Project No. 4.4.0.3.01

Date: Oct. 8, 1982

Sample No: URL-1 - 496.8Q

Original Length: 2.003 in.

Length after test: 2.008 in.

Irreversible expansion: 0.25%

Elapsed Time (min)	Temperature (°C)	Elongation (%)
0	21	0.00
3	33	0.00
6	57	0.00
9	85	0.01
12	114	0.03
15	143	0.053
18	173	0.08
21	204	0.12
24	235	0.17
26	255	0.205
28	276	0.24
30	296	0.28
32	316	0.318
34	335	0.355
36	355	0.395
38	375	0.438
40	395	0.483
42	416	0.530
44	436	0.580
46	456	0.630
48	476	0.685
50	496	0.745
52	516	0.808

Date: Oct. 12, 1982

Sample No: URL-1 - 527.5Q

Original Length: 1.998 in.

Length after test: 2.002 in.

Irreversible expansion: 0.20%

Elapsed Time (min)	Temperature (°C)	Elongation (%)
0	17	0.00
3	30	0.00
6	53	0.00
9	80	0.008
12	109	0.02
15	139	0.04
18	169	0.073
21	200	0.113
24	230	0.155
26	250	0.19
28	271	0.223
30	291	0.26
32	311	0.295
34	331	0.335
36	351	0.375
38	370	0.413
40	390	0.455
42	410	0.500
44	431	0.545
46	451	0.595
48	471	0.645
50	491	0.710
52	511	0.780

Project No. 4.4.0.3.01

Date: Oct. 13, 1982

Sample No: URL-1 - 592.7Q

Original Length: 2.003 in.

Length after test: 2.008 in.

Irreversible expansion: 0.25%

Elapsed Time (min)	Temperature (°C)	Elongation (%)
0	20	0.00
3	36	0.00
6	62	0.005
9	91	0.015
12	120	0.04
15	149	0.068
18	179	0.105
21	209	0.15
24	239	0.205
26	259	0.243
28	279	0.28
30	299	0.315
32	319	0.355
34	338	0.40
36	358	0.443
38	377	0.485
40	397	0.528
42	417	0.573
44	437	0.625
46	457	0.680
48	477	0.735
50	497	0.790
52	517	0.855

Date: Oct. 14, 1982

Sample No: URL-1 - 616.0Q

Original Length: 1.998 in.

Length after test: 2.001 in.

Irreversible expansion: 0.15%

Elapsed Time (min)	Temperature (°C)	Elongation (%)
0	22	0.00
3	33	0.00
6	55	0.00
9	82	0.01
12	111	0.025
15	140	0.05
18	170	0.085
21	200	0.125
24	230	0.170
26	250	0.20
28	270	0.23
30	290	0.26
32	310	0.298
34	330	0.335
36	350	0.375
38	371	0.42
40	392	0.46
42	412	0.503
44	432	0.555
46	452	0.610
48	472	0.665
50	492	0.730
52	513	0.798

Project No. 4.4.0.3.01

Date: Oct. 15, 1982

Sample No: URL-1 - 662.5Q

Original Length: 2.000 in.

Length after test: 2.004 in.

Irreversible expansion: 0.20%

Elapsed Time (min)	Temperature (^{o}C)	Elongation (%)
0	24	0.00
3	35	0.00
6	60	0.003
9	88	0.015
12	117	0.035
15	147	0.06
18	177	0.095
21	207	0.135
24	237	0.18
26	257	0.215
28	278	0.25
30	298	0.285
32	319	0.323
34	339	0.36
36	358	0.40
38	378	0.445
40	398	0.49
42	419	0.535
44	439	0.583
46	460	0.635
48	479	0.690
50	499	0.745
52	519	0.810

Date:

Sample No:

Original Length:

Length after test:

Irreversible expansion:

Elapsed Time (min)	Temperature (^{o}C)	Elongation (%)